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PHYSICS.—*Suggestions for frost protection.* KARL F. KELLERMAN, Bureau of Plant Industry.

The high thermal capacity of water has made possible the development of more or less elaborate enclosed systems for warming air spaces, such as living rooms, but very little attention has been paid to the utilization of water in efforts to protect orchards from frost. It would seem, however, that the rapid and efficient distribution of heat occasionally necessary in orchards, where modern systems of frost prevention are employed, could be controlled more satisfactorily and with less expense thru a development of water-heating systems.

The rapid evaporation when fine sprays of water are driven into the open air in summer weather has a cooling effect, due to the absorption from the air of a quantity of heat equal to the latent heat of vaporization of the water evaporated, which is so far in excess of the quantity of heat delivered to the system by the water introduced, that a short experiment under these conditions is misleading. The rapid decrease, with decreasing temperature, of the tension of aqueous vapor would make easily possible the artificial saturation of air at or below 0°. As soon as this artificial dew-point has been established the high calorific value of water vapor, or finely divided particles of water, would become operative.

Three methods of thus utilizing water appear possible: (1) the atomizing, or spraying by the use of power sprays, of fine mists

of water which might be warmed at a central station; (2) the suspension of pans holding small quantities of water above each of the fire pots now in use; and (3) the pumping, thru a permanent system of pipes, of steam generated at a central station and mixed with large quantities of air to prevent condensation in the pipes.

While there would be a considerable water economy in the use of steam by either the second or third methods, the feasibility of water heating will be sufficiently well illustrated by describing with approximate figures the theoretical possibilities of only the first method.

If we neglect for the moment the effect of evaporation and the presence of water vapor in the air, the heat liberated by 1 liter of water in cooling from 90° to 0° C. is, in round numbers, capable of raising the temperature of 296,100 liters of air from −1° to 0°C. To raise the temperature of a column of air 3.29 meters high and covering 1 hectare from −1° to 0° should therefore take approximately 111 liters of water at 90°. Assuming that the humidity of such a column of air was 80 per cent, and that at a temperature of −1° it would be saturated by 155 liters of water, the evaporation of the 31 liters of water required for saturation would absorb heat equivalent to that given off in cooling 184 liters from 90° to 0. The very small quantity of hot water, about 1 liter, required to raise the temperature of this aqueous vapor from −1° to 0° is almost negligible. For the rise of each degree, however, approximately 1.1 liters must go to saturate the column of air under discussion, and in evaporating this quantity of water heat is absorbed equivalent to that given off in lowering 7.4 liters of water from 90° to 0°. The total quantity of water at 90° which must be thoroly distributed to cause the initial rise from −1° to 0° of the air column 3.29 meters high, covering 1 hectare, is therefore 111 + 1 + 208.9 + 7.4 = 328.3 liters; the subsequent rise from 0° to 1° would require 111 + 1 + 1.1 + 7.4 = 120.5 liters of water at 90°; the increase from 1° to 2° would require 111 + 1 + 2.5 + 7.4 = 121.9 liters of water at 90°; and the increase from 2° to 3° would require 111 + 1 + 3.9 + 7.4 = 123.3 liters at 90°.

For a body of air 26 feet deep, covering 1 acre, 86.7 gallons of

water at 194°F. would be necessary to raise the temperature from 30.2°F. to 32°F., if the humidity was 80 per cent; 31.8 gallons more would be required to raise the temperature to 33.8°F.; 32.2 gallons additional for 35.6°F.; and 32.6 gallons additional for 37.4°F. Probably much larger quantities would be necessary in actual practice, due to loss of heat by convection currents, by imperfect distribution of the water and by the radiation continually taking place into the air outside of the heated zone.

In still air this proposed vapor system has the advantage of the protective quality of the fog thus artificially produced, due both to lessening the radiation from the earth and to the heat given off if the water particles actually began to freeze.

GEOLOGY.—*Some variations in Upper Cretaceous stratigraphy.*[1] TIMOTHY W. STANTON.

That the stratigraphic development of the Cretaceous has been different in distinct basins of sedimentation is well understood. No one would think of applying the same set of formation names to the Upper Cretaceous rocks of the Rocky Mountain region and to those of the Atlantic coastal plain or to those of the Pacific border. The physical conditions of sedimentation were very different and they have resulted in different lithologic successions and in more or less distinct faunal facies. The fact that there is great local variation, often within short distances, in a single area like that of the Rocky Mountains and adjoining Great Plains has been slower of recognition. It is true that the extension of more detailed work, especially when accompanied by areal mapping, has brought such local variations into prominence in many places but their importance has apparently often been overlooked by geologists, whose natural tendency is to apply the old established stratigraphic standards when they enter neighboring new fields, even when they realize that the standards must be warped and the new facts distorted in order to make the adjustment.

It may be of interest to cite a few cases of local variation, taking

[1] Published by permission of the Director of the United States Geological Survey. Presidential address delivered before the Geological Society of Washington, December 11, 1912.

the examples entirely from the region of the Rocky Mountains and adjacent plains, from central New Mexico northward to the Canadian boundary and confining them to that part of the Upper Cretaceous column which is within the limits of marine sedimentation for the region and does not involve any possible unconformities.

The classic upper Missouri section of Meek and Hayden[2] recognized only five formations, viz.:

	feet
Fox Hills sandstone	500
Fort Pierre shale	700
Niobrara limestone	200
Fort Benton shale	800
Dakota sandstone	400

(See Section No. 1, p. 58)

The thicknesses given were of course mere estimates based on rapid reconnaissance over great distances, the type localities being scattered from eastern Nebraska to central Montana. The section actually passed far to the west of the area in which the Niobrara limestone is developed and crossed a region where a large part of the Pierre shale is represented by littoral, estuarine, and terrestrial deposits. With his standard Cretaceous section recognizing only two sandstones, one at the top and the other at the bottom, it is no wonder that Hayden wavered in his assignment of the sandstones beneath the Judith River formation, sometimes referring them doubtfully to the Dakota and later correlating them with the Fox Hills.

The geologists of the Fortieth Parallel Survey found that the Niobrara did not retain its lithologic character so as to be recognizable over a large part of the area surveyed by them and they therefore attempted to map as one great shale group all the rocks lying between the Dakota and the Fox Hills. They also appreciated the fact that the Cretaceous sediments in the neighborhood of the Wasatch Mountains, at Coalville, Utah, for example, include an unusual development of sandstones thruout the section, which they attributed to near shore conditions, but if they did not succeed in making a consistent map and section of the Upper Cretaceous it was largely because they adopted the

[2] Proc. Acad. Nat. Sci., Philadelphia, 1861, p. 419.

idea that there are no important or persistent sandstones between the Dakota and the Fox Hills, while the fact is that in the area of their map this interval includes two thick coal-bearing formations in which sandstones are the dominant feature.

Evidently at least one new standard section, with modified nomenclature, was needed and this was furnished in southwestern Colorado. Holmes and others on the Hayden Survey nearly forty years ago had shown that the stratigraphic development differed considerably from that of the sections in the upper Missouri region and in Colorado east of the mountains. In the course of the areal work under the direction of Cross, the grouping and nomenclature of Holmes' section were modified and published in the La Plata and Telluride folios[3] from which the following descriptions are condensed (Section No. 2, p. 58):

Lewis shale. More or less sandy gray or drab shale with thin lenses or concretions of impure limestone. Thickness in Durango quadrangle, 2000 feet.

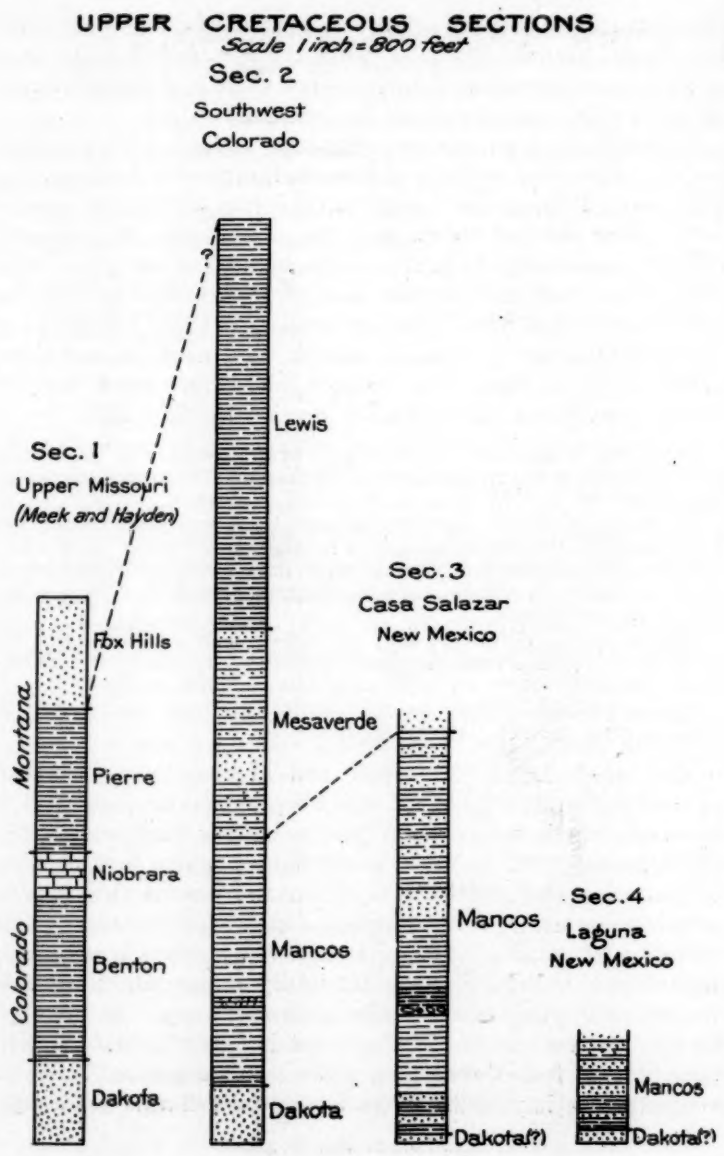
Mesaverde formation. Alternating sandstones and shales with occasional marls or thin limestones and a number of coal beds. Lower 250 feet form a transition from Mancos shale followed by heavy sandstone 125 feet thick. At top a massive sandstone 25 feet thick. Total thickness, 1000 feet.

Mancos shale. Soft, dark-gray or almost black carbonaceous clay shale containing thin lenses or concretions of impure limestone. Thickness, 1200 feet.

Dakota sandstone. Gray or rusty brown quartzose sandstone with variable conglomerate. 100 to 300 feet.

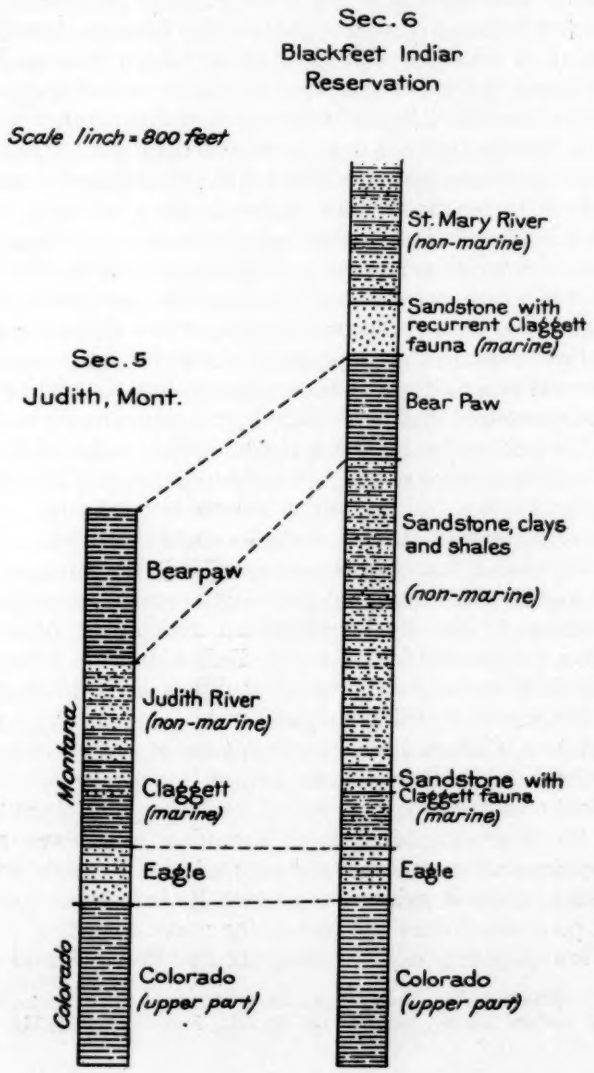
The names Lewis, Mesaverde and Mancos have since been applied with varying success and acceptability thruout western Colorado, northwestern New Mexico, eastern Utah, and southern Wyoming. As described in the different areas each of these formations varies greatly in thickness and considerably in lithologic character. For the purpose of showing the nature of this variation let us take the Mancos shale which over a large area is limited above and below by the easily recognized Mesaverde formation and the Dakota sandstone, respectively. In the type section just west of the La Plata quadrangle the Mancos consists of 1200 feet of dark gray shale containing some lenses or concretions of impure limestone, but in the Telluride quadrangle

[3] Geologic atlas of the United States, Folio 60 and 57.


UPPER CRETACEOUS SECTIONS
Scale 1 inch = 800 feet
Sec. 2
Southwest
Colorado
Sec. 1
Upper Missouri
(Meek and Hayden)
Montana
Colorado
Fox Hills
Pierre
Niobrara
Benton
Dakota
Lewis
Mesaverde
Mancos
Dakota
Sec. 3
Casa Salazar
New Mexico
Mancos
Dakota(?)
Sec. 4
Laguna
New Mexico
Mancos
Dakota(?)

UPPER CRETACEOUS SECTIONS

Scale 1 inch = 800 feet



a short distance to the north it is said to be 2000 feet thick and is described as "gray sandy shale with calcareous bands and sandstones." Eastward, however, for nearly 100 miles thru the La Plata and Durango quadrangles and on to Monero, New Mexico, the work of Schrader[4] and Gardner[5] has shown that the Mancos shale maintains about the same thickness and character as at the type locality. From Monero southward along the eastern border of the great San Juan area, past El Vado to Gallina and beyond, a distance of about 50 miles, it continues to be essentially a shale with no conspicuous sandstone intercalations. On this point the observations of Lee and Stanton on a recent reconnaissance from Albuquerque to Monero confirm the descriptions of Gardner who mentions a sandstone 30 feet thick, 275 feet below the top of the Mancos, 10 miles north of Gallina and states that farther south the upper part of the formation consists of 300 feet of argillaceous sandstone and sandy shale grading up into the Mesaverde formation. The important point to be remembered is that so far the lower three-fourths of the Mancos contains no sandstones except a band usually about 50 feet thick, of yellowish thin-bedded, shaly, somewhat calcareous sandstone and sandy shale, characterized by *Ostrea lugubris*, *Scaphites warreni*, and *Prionocyclus wyomingensis*, representing one of the most useful, widespread and persistent faunal zones in the Upper Cretaceous of the Rocky Mountain region. At Mancos this horizon is about 400 feet above the Dakota but the distance from the Dakota varies considerably, doubtless on account of variation in the rate of sedimentation.

South of Gallina along the west base of Naciemento Mountains structural complications and an overlap of the Tertiary prevent continuous observation of the Mancos for about 20 miles but the overlying Mesaverde is readily recognized when it reappears and is continuously exposed to the neighborhood of Cabezon where it swings west with a low northerly dip. From that point southward the underlying rocks, including the Mancos, are splendidly exposed along the Rio Puerco for 35 miles to

[4] U. S. Geol. Survey, Bull. 285, pp. 241–258.
[5] U. S. Geol. Survey, Bull. 341, pp. 335–351. Jour. of Geology, **18**: 702–741.

San Ygnacio where they have been described in general terms by Herrick[6] and Johnson and in greater detail by W. T. Lee.[7] The Mancos is here expanded to a thickness of fully 2000 feet and it includes several cliff-making sandstones so that its general aspect is greatly altered (Section No. 3, p. 58.)

The upper 800 feet or more consist of more or less sandy shale, generally weathering yellowish, with many bands and lenses of soft sandstone. Beneath this is a massive, yellowish, cliff-making sandstone approximately 100 feet thick separated by 350 feet of dark shale from the brownish, shaly, calcareous sandstone which forms the zone of *Ostrea lugubris* and *Scaphites warreni* already mentioned. Beneath this zone is another dark shale, about 500 feet thick, followed by Herrick and Johnson's "Tres Hermanos" sandstone which consists of two distinct massive beds 66 feet and 37 feet thick, respectively, separated by about 50 feet of dark shale. Another dark shale, 55 to 60 feet thick, intervenes between the basal bed of the "Tres Hermanos" sandstone and another somewhat variable sandstone which seems to represent the Dakota, although it is here only from 25 to 40 feet thick.

The section of the Mancos just described is all well exposed in the west side of Prieta Mesa on the Rio Puerco near the village of Casa Salazar and the sandstones, especially the "Tres Hermanos," make conspicuous cliffs on frequent exposures for 25 miles along the Rio Puerco. There are minor variations in the thickness of individual members but the general character is consistent thruout this distance. According to the faunal evidence the 1200 feet of rocks immediately above the Dakota (?) should all be correlated with the Colorado group, and this part of the section instead of being all shale, as in the typical Mancos, includes at least 200 feet of sandstone in three massive beds. A still further increase in the sandstones of the part of the section corresponding to the "Tres Hermanos" sandstone and associated

[6] Geology of the Albuquerque sheet (New Mexico). Denison Univ. Sci. Lab. Bull. vol. xi, art. ix, pp. 175–239.

[7] Stratigraphy of the coal fields of northern central New Mexico. Bull. Geol. Soc. Am. **23**: 571–685.

shales may be seen at Laguna, New Mexico, about 30 miles southwest of the exposures just described. Here within the 350 feet immediately above the Dakota (?),[8] which is 85 feet thick, there are three massive cliff-making sandstones instead of two, and the overlying 75 feet beneath the lava cap is a sandy shale with soft sandstone bands. Marine fossils are abundant and characteristic so that there is ample evidence for detailed correlation. (Section No. 4, p. 58.)

These New Mexican exposures may perhaps all be legitimately called Mancos though it may be questionable practice in the localities most remote from well recognized Mesaverde. In southern Utah where the name is not appropriate the equivalent of the lower, or Colorado portion of the Mancos may still be very definitely determined by means of two or more paleontologic zones which are common to southern Utah and the part of New Mexico which has just been discussed. Sections recently studied by Richardson[9] in Kanab Valley and further west in the Colob plateau show a thickening of this part of the section and a greater development of sand stone as compared with the New Mexican section, together with the intercalation of coal beds and brackish and fresh-water sediments in the basal portion. They also show according to unpublished data great local increase in the relative proportion of sandstone and in the total thickness of the sediments in passing a short distance west from Kanab Valley.

Some of these southern Utah sections show close resemblance to the Coalville section in northern Utah and it in turn has many points in common with the immensely thick section described by Veatch[10] and Schultz[11] in Uinta County, Wyoming, the southwest corner of the state. In the Uinta county section beneath the "Laramie" formation in descending order come the Hilliard shale, consisting of gray to black sandy shale and shaly sandstones

[8] Darton has published a section of the Cretaceous rocks exposed 2 miles northeast of Laguna (U. S. Geol. Survey Bull 485, p. 60) in which numbers 8 and 9 correspond to the Dakota(?) of my section. The underlying rocks, over 300 feet in thickness are suggestive of Morrison.

[9] U. S. Geol. Survey, Bull, 341, pp. 379–400.

[10] U. S. Geol. Survey, Prof. Paper No. 56.

[11] Ibid., Bull 316, pp. 212–241.

5300 to 6800 feet thick; the coal-bearing Frontier formation with yellow and gray sandstone, yellow, gray and black carbonaceous shales and numerous coal beds, 2200 to 2600 feet thick; the Aspen shale, 1500 to 2000 feet thick; and the fresh- and brackish-water Bear River formation which attains a thickness of 5000 feet.

For the present purpose the chief interest in this great section lies in the fact that it is so unlike the sections in areas a short distance to the east, as at Rock Springs, 70 miles east, described by Schultz,[12] and in the Rawlins district, 80 miles farther east, described by Veatch,[13] Ball,[14] and E. E. Smith.[15] In these more eastern sections the Bear River is absent as might be expected. Its place in the section is occupied by a thin representative of the Dakota sandstone. The Frontier is faintly recognizable in a comparatively thin sandstone-bearing formation without coal. It is overlain by a great mass of dark clay shale, sandy shale and shaly sandstone 4000 to 5000 feet thick followed by a thick and very important coal-bearing formation and a marine shale for which the names Mesaverde and Lewis, respectively, have been brought in from Colorado. Assuming that Mesaverde is here correctly identified the logical treatment would be to apply the name Mancos to all the rocks between the Mesaverde and the Dakota but on account of the great thickness of those beds and their partial differentiation into members that have come in from other areas on the east and west this has not yet been done. The Mesaverde and Lewis together apparently represent, in part at least, the Hilliard shale of the Uinta County section. Both these sections show very great thickening so that the total sediments from the base of the Mancos or Colorado up, amount to more than 10,000 feet. The chief difference lies in the fact that the Uinta County section develops a great coal-bearing formation of sandstone and shale in the lower part within the equivalent of the Colorado group, while the Rock Springs and more eastern sections have no coal in that part of the column but

[12] U. S. Geol. Survey, Bull. 341, pp. 256–282.
[13] Ibid., Bull. 316, pp. 244–260.
[14] Ibid., Bull. 341, pp. 243–255.
[15] Ibid., Bull. 341, pp. 220–242.

develop a similar great coal-bearing formation in the upper or Montana portion. These widely different neighboring sections seem to me to represent the varied and shifting sediments laid down in and on the borders of a single body of water. Slight warping of the surface, or local changes in the rate of sedimentation from whatever cause, would serve to shift the area of sea and coastal swamp from time to time.

One more standard section, with the changes and variations in its formations as they are followed away from their typical area, remains to be examined. In connection with their stratigraphic study of the Judith River formation Stanton and Hatcher[16] established the following succession in northern central Montana:

Bearpaw shale. Dark clay shale with marine fauna, 750 feet?

Judith River formation. Variable shales and soft sandstones with dinosaurs and other reptiles and fresh- and brackish-water invertebrates, 500 feet.

Claggett formation. Dark clay shale with several beds of sandstone especially in the upper portion. Marine fossils throughout—those of the sandstones containing many Fox Hills species, ± 400 feet.

Eagle sandstone. White, gray and yellowish sandstone with shale and coal in upper part. Marine shells, land plants and dinosaurs, 200 to 300 feet.

Colorado shale. Dark marine shale, 800 feet or more.

(See Section No. 5, p. 59.)

Compared with the southwestern Colorado section the top of the Colorado shale in this section is believed to be somewhat lower in the general column than the top of the Mancos but with this exception the Eagle, Claggett, and Judith River, taken together, are comparable in a general way with the Mesaverde, and the Bearpaw is approximately in the position of the Lewis.

The formations above the Colorado shale described in the neighborhood of Judith, Montana, were found to be easily recognizable along the Missouri River in the type area above and below the mouth of Judith River; on Milk River from the neighborhood of Havre to the Canadian boundary and beyond; and southward in the valley of the Musselshell. These formations have since been mapped by the geologists of the Fuel Section

[16] U. S. Geol. Survey, Bull. 257, pp. 11–14.

of the Survey over large areas in Montana and the limits of their areal distribution are now fairly well known. The most persistent is the Eagle sandstone which has been recognized as far south as the Bighorn Basin and northwest to the western limit of the Great Plains in northern Montana. The overlying Claggett, Judith River and Bearpaw formations in many localities lose their distinguishing features within shorter distances. None of them has been recognized as such east of the typical area. In that direction the fresh- and brackish-water beds of the Judith River doubtless soon grade laterally into marine shale so that there is no basis for distinguishing Claggett and Bearpaw from Pierre. Toward the south and west, on the other hand, the marine sediments of the Claggett and Bearpaw tend to be replaced and represented by estuarine and continental deposits.

A striking example of rapid variation of this kind has been described by Stone and Calvert[17] in the area surrounding the Crazy Mountains where within a short distance the Claggett, Judith River and Bearpaw finger out, and at last completely lose their identity in andesitic tuffaceous deposits which have been included in the Livingston formation.

Conditions somewhat similar, except for the absence of volcanic material, are found in the Bighorn Basin where the Eagle sandstone is recognized but the attempts to apply Claggett, Judith River and Bearpaw to the overlying formations have not been much more successful than the earlier attempts to apply the Meek and Hayden nomenclature in the same area. The marine Bearpaw shale just enters the northern end of the basin as a thin bed which soon wedges out completely. The reports of Woodruff[18] and Washburne[19] and the unpublished, more detailed work of Hewett show that over a large part of the Bighorn Basin especially on the west side there are no marine sediments above the Eagle sandstone, which is itself there only in small part marine, and that the thick interval between the Eagle and the well-identified Fort Union is occupied by fresh-

[17] Economic Geology, **5**: 551–557, 652–669, 741–764, 1910.
[18] U. S. Geol. Survey, Bull. 341, pp. 200–219.
[19] Ibid., Bull. 341, 165–199.

water or continental deposits which, while very irregular and varied, are yet uniform throughout in the character of their variation. That the time equivalents of Claggett, Judith River and Bearpaw, as well as the overlying Lance, are all included in these non-marine deposits seems to me the most reasonable assumption, tho it is perhaps not yet capable of complete proof.

Another area in which there is a different development of the rocks between the Eagle sandstone and the Bearpaw shale is the Blackfeet Indian Reservation in Montana just south of the Canadian boundary and east of the Rocky Mountain front somewhat more than 100 miles northwest of Judith. (Section No. 6, p. 59.) During the past two seasons the areal mapping and detailed stratigraphy have been done by Mr. Eugene Stebinger thru whose courtesy I am permitted to make these general statements based on his detailed work and on data obtained during two visits which I have made to the field. The Eagle sandstone resting on Colorado shale with a low dip to the west is normally developed and forms a conspicuous escarpment extending from near Cutbank in a northerly or northeasterly direction to the Canadian line. The Bearpaw shale of typical character and with a marine fauna, here somewhat meagerly developed, is nearly 500 feet thick. Between these two formations there are almost 2000 feet of sediments in which no practicable formation boundaries can be drawn and which Stebinger has therefore mapped as a unit altho it must include the time equivalents of both Claggett and Judith River. Lithologically it has a closer resemblance to Judith River and like that formation it is essentially non-marine. It contains Unio, Viviparus, and other fresh-water shells at various horizons from the top to within 200 feet of the base. There are also dinosaurs and land plants, and locally thin brackish-water beds are found with Ostrea, Corbula and Corbicula, especially at the top and in the lower portions. No evidence of marine fossils or sediments had been found in the formation until September of this year when at the town of Cutbank I found marine fossils locally abundant in a sandstone 50 feet thick which forms the top of the east wall of the gorge of Cutbank Creek about half a mile south of the town. The horizon is not

more than 300 feet above the Eagle sandstone and hence should be in the equivalent of the Claggett formation. Or, to locate it more accurately, according to Mr. Stebinger it is immediately above the horizon of a thin coal which he has traced down the creek from the "Allison mine" a few miles northwest.

Now the marine fossils found at this place belong to the fauna which occurs in the sandstones of the Claggett formation at its type locality and include among the more abundant and conspicuous forms *Tancredia americana, Cardium speciosum, Mactra formosa,* etc. This is the fauna which in the past Meek, White, Stanton, and others have called a typical Fox Hills fauna because these conspicuous and abundant forms—the dominant species as Prof. H. S. Williams calls them—do recur in the Fox Hills sandstone at the top of the Cretaceous column.

This recurrent fauna when it reaches the Fox Hills is, of course, not absolutely identical with the sandstone fauna of the Claggett, but there are enough conspicuous, identical species to make identification of the horizon uncertain unless the collections are complete or the stratigraphic details fully known. Recurrent faunas are often troublesome and embarrassing to the stratigraphic paleontologist and still more so to the stratigrapher who is not a paleontologist. It is even difficult to prove that the fauna is recurrent at a higher horizon when the two localities are as far separated as central Montana and the middle of South Dakota, as they are in the case of the type localities of the Claggett and the Fox Hills, although the stratigraphic position of the Claggett was determined in 1903 independently of the evidence of that particular fauna and in contradiction of the interpretation that had been placed on it. There are also many localities now known where the stratigraphic position of the fauna in question, at one or the other of the two horizons, is well determined. For these reasons the argument set forth in a recent article by A. C. Peale[20] that the upper sandstones of the Claggett are identical with the Fox Hills is altogether fallacious in so far as it is based on lithologic and faunal resemblances. Nevertheless it was gratifying to find this Claggett-Fox Hills fauna in the normal position of

[20] Jour. of Geology, **20**: 530-549, 640-652, 738-757, 1912.

the Claggett formation and again recurring about 2000 feet higher in the same section where there is no reason to question the structure or stratigraphic position. At Cutbank the fossils are about 300 feet above the Eagle or more than 1500 feet below the Bearpaw. From this locality there are practically continuous exposures down Cutbank Creek to its mouth where the base of the Eagle is exposed. Thence westward up Two Medicine Creek there are continuous exposures and simple structure up to and thru the Bearpaw with its 500 feet of dark shale. Above the Bearpaw is a sandstone which makes conspicuous cliffs near the Holy Family Mission (Family P. O.) on Two Medicine Creek. Here and at other exposures farther west on the creek it yielded *Tancredia americana*, *Cardium speciosum*, Mactra, etc., identical with those found at the much lower horizon, together with a number of other forms not found there. This sandstone is approximately in the position of the Fox Hills and is doubtless the same sandstone which Dawson identified as Fox Hills in the adjacent area on the north, tho from the evidence at hand it would be rash to say that it is strictly identical with the Fox Hills of South Dakota. At most localities where it has been examined in the Blackfeet reservation it has proved unfossiliferous or yielded only *Ostrea subtrigonalis* and other brackish-water forms which are found both in Dawson's St. Mary River formation above it and in the beds beneath the Bearpaw, but here, on Two Medicine Creek, there was an incursion of strictly marine water with an abundant fauna of Fox Hills type.

After this brief digression in pursuit of a recurrent fauna let us return, for a few moments, to the main topic, which is contemporary variation in sedimentation and its bearing on stratigraphy and geological history. The sedimentary records of the Blackfeet country, aided by the paleontologic evidence, show that during the long quiet deposition of the Colorado shale and while the Eagle sandstone was being laid down by the stronger currents of the shallowing sea the physical conditions there were about the same as in a large area on the east and southeast. Later, during Claggett time, while purely marine conditions still prevailed a short distance to the east, near Judith, for example,

the Blackfeet country was slightly elevated so that it was occupied by coastal swamps and lagoons only a few feet above tide into which slight depressive movements occasionally brought local and temporary brackish waters and still more rarely a brief incursion of the sea, as is proved in one case by the fossils found at Cutbank. The Bearpaw shale marks a more important marine incursion which probably covered the whole area and continued for some time though it is questionable whether it lasted as long here as it did in central Montana. At the close of Bearpaw sedimentation there was clearly another considerable period of transition when the area wavered near tide level and received first marine and then brackish-water sediments before land conditions were at last permanently established.

We are now in position to understand the difficulties which Dawson[21] encountered in describing and interpreting his section of the "Belly River series" along Milk River north of the international boundary. It was another case of applying the terminology of a single section thru a long stretch of country in which the stratigraphic development varied. In the eastern portion where Dawson got the best evidence that the "Belly River" is intercalated between two marine formations the section is like that at the mouth of Judith River while in the western portion it is the same as in the Blackfeet Indian reservation. In 1903 Hatcher and Stanton visited the localities near Pakowki Lake and correctly identified as Claggett the "lower dark shale" there exposed beneath the "Belly River," thus establishing the identity of the "Belly River" of that section with the Judith River formation. The mapping of Stebinger has now shown that the "lower dark shale" on the escarpment of Rocky Spring Plateau about 40 miles west of Pakowki Lake is Colorado shale and Dawson's "Belly River" from that point west includes the Eagle sandstone and all the overlying rocks to the base of the Bearpaw. Between these two localities the marine Claggett shale has merged into non-marine sandstones and shales.

In conclusion the general statement is justified that the Upper Cretaceous sediments of the Rocky Mountain region show as

[21] Geol. Survey of Canada, Rept. for 1882–83–84, pp. 111 C–126 C.

great contemporary local variation in a single basin as may be found in the deposits now forming along any modern coast. The local character of many of the beds, the rapidity with which they merge laterally into others of unlike lithologic character make it necessary to use many local formation names. They should also make the geologist cautious in his interpretations of the absence of any particular bed or formation. When, for example, a sandstone which forms the top of the marine Cretaceous section in one area is absent in another area its absence may be due to erosion, but its apparent absence may also be due to the fact that the sandstone is there represented by a shale or by non-marine deposits of a totally different character.

GEOCHEMISTRY.—*Chalcocite deposition.* ARTHUR C. SPENCER, Geological Survey.[1]

The most common secondary sulfide in many copper mining districts is chalcocite, occurring under conditions which indicate that deposition has taken place from solutions containing copper sulfate. It is not difficult to show that the direct or indirect source of this dissolved copper compound is chalcopyrite which may be termed primary, and it is a matter of observation that the same double sulfide of iron and copper is a very effective precipitant or localizer of chalcocite. Pyrite has been usually regarded as the most common nucleus for secondary chalcocite, but in certain districts chalcopyrite must be recognized as occupying this rôle instead of pyrite. The presence and proportion of chalcocite in ores now being mined on a large scale in several districts determines their commercial value. This is notably true of the so-called porphyry ores in which the metallic sulfides are thoroly disseminated thru great masses of rock.

In 1903 H. V. Winchell[2] published the results of experiments devised to indicate the probable conditions under which chalcocite has been deposited in the veins of the Butte district from waters carrying cupric sulfate. The determining agent in the deposition was thought to be SO_2, and later[3] A. N. Winchell

[1] Published by permission of the Director.
[2] Bull. Geol. Soc. Am. **14**: 269–276. 1903.
[3] Economic Geology **2**: 290–294. 1907.

showed that SO_2 is actually one of the products when pyrite undergoes oxidation. In a recent discussion of this subject Tolman,[4] who was associated with H. V. Winchell, has used the results of these two investigations as the basis for an understanding of the chemistry of secondary chalcocite. Previously, however, it had been argued by Lindgren,[5] that the scheme suggested by Winchell is open to criticism because no indication is given as to how SO_2 generated in the upper oxidizing zone could reach the situs of chalcocite deposition, since it would be destroyed in transit by contact with products of pyrite decomposition.

On its face this reasoning against the Winchell hypothesis appears to be adequate, but the fuller analysis here presented tends to show that SO_2 may still be an actual factor in the reaction. Since the writer does not have that unwavering faith which would find in every balanced chemical equation a truth of fundamental value, it is recognized that the equations of the series here given afford no demonstration. They do however, furnish a convenient shorthand to assist in analytical discussion, and some of them are allowable expressions of known actions.

Chalcocite, deposited in molecular replacement of primary sulfides, is a side product of the culminating reaction in a series of oxidizing effects which occur in situations where water and air penetrate from the surface to cupriferous sulfide-bearing rock or vein stuff. The full series of reactions may be divided conveniently and logically into three groups, assignable to a higher, an intermediate, and a lower position in the body of sulfide-containing material. If considered with respect to the minerals which suffer decomposition these reactions present a succession of oxidations, while with respect to the active solution the changes are of course as consistently in the direction of reduction. Group I comprises the reactions of complete oxidation on the upper edge of an ore body where free oxygen is present. Group II comprises reactions ensuing at slightly greater depth and involving oxidation of sulfides (both primary and secondary) by contact with ferric sulfate. Group III, occurring at still greater

[4] Min. Sci. Press **106**: 42. 1913.

[5] Copper deposits of Clifton-Morenci. Prof. Paper U. S. Geol. Survey No. 43, p. 184. 1905.

depth, includes oxidation of sulfides (primary only) by contact with cupric sulfate. Or, if the solution is considered rather than the minerals with which it comes into contact, the three groups of reactions involve successively depletion of free oxygen; reduction of ferric to ferrous sulfate; and finally the decomposition of cupric sulfate derived from previous reactions. This last reaction is, as a whole, one of double decomposition in which soluble ferrous sulfate and insoluble cuprous sulfide are formed at the expense of cupric sulfate and pyrite or chalcopyrite.

Several of the equations which may be written to represent tentatively the three sets of reactions outlined above are current in the literature treating of sulfide oxidation and enrichment. Others have been supplied by the writer to complete what may be called natural or obvious sequences. It is believed that no one of the equations presented contemplates the concomitance of bodies that are chemically incompatible.

Group I. Intermediate equations and final equation representing reactions in the upper zone of complete oxidation:

$$FeS_2 + 6O = FeSO_4 + SO_2 \quad (1)$$

$$FeS_2 + H_2O + 7O = FeSO_4 + H_2SO_4 \quad (2)$$

$$2FeSO_4 + H_2SO_4 + O = Fe_2(SO_4)_3 + H_2O \quad (3)$$

$$2FeS_2 + H_2O + 15O = Fe_2(SO_4)_3 + H_2SO_4 \quad (4)^6$$

Group II. Intermediate equations and final equation indicating oxidation of pyrite by ferric sulfate. This salt is one of the soluble products indicated by equation(4):

$$FeS_2 + Fe_2(SO_4)_3 = 3FeSO_4 + 2S \quad (5)$$

$$S + Fe_2(SO_4)_3 = 2FeSO_4 + 2SO_2 \quad (6)$$

$$SO_2 + 2H_2O + Fe_2(SO_4)_3 = 2FeSO_4 + 2H_2SO_4 \quad (7)$$

$$FeS_2 + 8H_2O + 7Fe_2(SO_4)_3 = 15FeSO_4 + 8H_2SO_4 \quad (8)^7$$

To this group of equations may be added one representing the decomposition of chalcocite and the simultaneous reduction of ferric sulfate:

[6] Derived from equations (2) and (3) by substitution. Where chalcopyrite is present a corresponding equation will indicate the formation of $CuSO_4$ instead of H_2SO_4.

[7] Derived from the foregoing equations. Note that(8) is strictly comparable with (4).

$$Cu_2S + 2Fe(SO_4)_3 = 4FeSO_4 + S + 2CuSO_4$$

Group III. Intermediate equations and final equation indicating the last stage of pyrite oxidation where cupric sulfate is the reagent, and chalcocite a side product:

$$2FeS_2 + 2CuSO_4 = Cu_2S + 2FeSO_4 + 3S \quad (9)$$

$$3S + 2CuSO_4 = Cu_2S + 4SO_2 \quad (10)$$

$$5SO_2 + 6H_2O + 2CuSO_4 = Cu_2S + 6H_2SO_4 \quad (11)$$

$$5FeS_2 + 14CuSO_4 + 12H_2O = 7Cu_2S + 5FeSO_4 + 12H_2SO_4 \quad (12)[8]$$

Equations analogous to (12) but involving chalcopyrite and sphalerite in place of pyrite are the following:

$$5CuFeS_2 + 11CuSO_4 + 8H_2O = 8Cu_2S + 5FeSO_4 + 8H_2SO_4 \quad (13)$$

$$5ZnS + 8CuSO_4 + 4H_2O = 4Cu_2S + 5ZnSO_4 + 4H_2SO_4 \quad (14)$$

Here, in the interest of completeness, may be introduced the Stokes equation representing the change pyrite to covellite, and the analogous equation involving chalcopyrite:

$$4FeS_2 + 7CuSO_4 + 4H_2O = 7CuS + 4FeSO_4 + 4H_2SO_4 \quad (15)[9]$$

$$CuFeS_2 + CuSO_4 = 2CuS + FeSO_4 \quad (16)$$

It is to be noted that equation (5) which is given by Stokes[10] is stated by him to conform with the observation that on exposure to the air, pyrite yields free sulfur which may be detected by extraction with ether. Also equation (6) conforms with the results of experimental oxidation of pyrite by H. N. Winchell[11] and is in accord with observation as recorded by Gottschalk and Buehler.[12]

Of the expressions under Group III, equations (9) and (10) are seen to be analogous to equations (5) and (6), and if the latter are real it may be thought likely that the former are. In any event it is almost obvious that equations (9) to (11) were used

[8] Derived from the foregoing equations. This expression, which is to be credited to Stokes, was first printed in the work of Lindgren already cited (p. 183.) where the reader is led to infer that the equation was tested by quantitative determination of the H_2SO_4 formed. See also Stokes, Economic Geology, **2**: 22, 1907.

[9] Stokes, H. N., loc. cit.

[10] U. S. Geol. Survey Bull. 186, pp. 15 and 19, 1901.

[11] Loc. cit.

[12] Economic Geology **7**: 16, 1912.

by Stokes in deducing equation (12), and it is perhaps sufficiently accurate to regard this chemist as their sponsor. As equation (10) is to this extent plausible it may be suggested, not inappropriately, as offering a link between the two lines of investigation due to Winchell and Tolman on the one hand and to Stokes on the other. Equation (10) shows at least the possibility that SO_2 may be a product of chemical reaction during the final stage of oxidation as well as during earlier stages; or, in other words, it indicates that SO_2 may be evolved in the situs of chalcocite deposition as well as in those situations where ferric sulfate undergoes reduction, as suggested by equation (6), or where free oxygen is being used as in equation (1). In this manner it may be possible to avoid the objection raised by Lindgren.

Although the principal object of the present communication is attained in a tentative reconciliation of the suggestion due to Winchell with the points urged against it by Lindgren, occasion may be taken to present certain additional considerations pertaining to the Stokes equation and analogous expressions.

If the equations given are accepted as affording a working hypothesis, it might be found that under experimental conditions the attack of cupric sulfate on pyrite, or preferably on chalcopyrite, could be initiated in the presence of a moderate amount of SO_2 and that when thus started the conversion might continue without further aid, proper environment being maintained by the presence of SO_2 currently evolved. There are good reasons for the statement that chalcopyrite is less stable than pyrite in solutions containing salts of copper. For the deposition of chalcocite, the chemical mechanism involved must be essentially identical in either case.

When the pyrite and chalcopyrite equations are compared with respect to volume relations, in the conversion to chalcocite by molecular replacement the former is found to demand expansion in the ratio 2 : 3, while the latter requires little if any volume increase. Accepting both equations, we might anticipate that pyrite would prove to be a less efficient agent than chalcopyrite in chalcocite deposition. In the porphyry ore at Ely, Nevada, where grains of primary chalcopyrite and pyrite occur side by side the former are always more deeply coated with chalcocite

than the latter and usually the ratio of film thicknesses is greater than 3 : 1. The suggested explanation is that replacement continues only so long as space can be found for the necessary expansion, so that where pyrite is the core mineral for chalcocite deposition reaction would be inhibited much sooner than where chalcopyrite is the nucleus.

Essentially the same volume relations appear in using the simplest possible expressions for complete reaction between cupric sulfate and pyrite or chalcopyrite when the product is covellite—equations (15) and (16). It seems safe to predict, therefore, that chalcopyrite will be shown to be a more favorable nucleus than pyrite for receiving secondary covellite.

The volume relations required by equation (14) show no essential change, if sphalerite is transformed into chalcocite—that is the ratio is nearly 1 : 1, a slight expansion being found by calculation. On the other hand, when sphalerite is converted to covellite, if the reaction goes on molecularly according to the simplest equation which may be written, there is a diminution of volume in the ratio 12 : 11. Other things being equal, it would seem that volume relations favor the deposition of covellite rather than chalcocite where sphalerite comes into contact with copper sulfate solution.

Altho the equations which have been given as a basis for the foregoing discussions are speculative, it is hoped that the systematic arrangement here presented may hasten experimental work which is needed before the chalcocite problem can be solved.

MINERALOGY.—*Immense bloedite crystals.* Preliminary note. WALDEMAR T. SCHALLER, Geological Survey.

A recent find of bloedite by Mr. Hoyt S. Gale of the Geological Survey, is remarkable for the immense size of the crystals. An extensive deposit of soda forms a crust on Soda Lake, in Carriso Plain, San Luis Obispo County, California. This deposit has been described by Arnold and Johnson[1] who give a detailed analysis of the saline crust which shows it to be a nearly pure sodium

[1] Bull. 380, U. S. Geological Survey, p. 369. 1908.

sulfate with 1.66 per cent MgO. In the black mud below this crust were found the isolated crystals of bloedite—a hydrous magnesium-sodium sulfate with 12 per cent MgO.

The larger crystals have a dark almost black appearance when the superficial covering of grey mud is removed tho the smaller crystals are nearly colorless, the black appearance being due to impurities. In places the larger crystals are likewise nearly colorless and translucent and in small pieces transparent. In fact, selected fragments are clear and glassy and together with the lack of cleavage, greatly resemble quartz fragments.

The largest crystal at present on hand measures $16\frac{1}{2}$ cm. ($6\frac{1}{2}$ inches) by $10\frac{1}{2}$ cm. by $3\frac{1}{2}$ cm. and weighs 652 grams. The crystals are flattened somewhat parallel to the base and show the following forms:

Large.....$c(001)$, $d(011)$, $m(110)$
Medium.....$n(210)$, $p(111)$
Small.....$q(\bar{2}01)$, $s(\bar{2}11)$, $u(\bar{1}11)$, $x(\bar{1}21)$

The measurements were made with a contact goniometer and gave the following results:

FORM	MEASURED	CALCULATED
$m(110) : p(111)$	47°	46° 42′
$c(001) : q(\bar{2}01)$	50	50 06
$c(001) : p(111)$	36	36 55
$n(210) : n'''(2\bar{1}0)$	68	67 06
$m(110) : m'''(1\bar{1}0)$	105	105 58
$d(011) : d'(0\bar{1}1)$	67	66 46
$c(001) : s(\bar{2}11)$	55	55 $16\frac{1}{2}$
$c(001) : u(\bar{1}11)$	43	42 05

The form $x(\bar{1}21)$ was determined by zonal relations.

An analysis of selected pure material gave the following:

Analysis of bloedite from California

H_2O	21.37
MgO	11.93
Na_2O	18.26
SO_3	48.11
	99.67

These proportions are close to those required by the formula $Na_2Mg(SO_4)_2.4H_2O$.

PHYSIOLOGICAL BOTANY.—*The formation of leafmold.*[1]

FREDERICK V. COVILLE, Department of Agriculture.

When the leaves of a tree fall to the ground they begin to decay and ultimately they are disintegrated and their substance becomes incorporated with the other elements of the soil. The same thing happens with the leaves, stems, and roots of herbaceous plants. Such organic matter is one of the chief sources of food for plants, and its presence in the soil is therefore of fundamental importance in the maintenance of the vegetative mantle of the earth.

In a series of experiments from 1906 to 1910 the speaker showed that a condition of acidity is a primary requirement of the blueberry, laurel, trailing arbutus, and other plants associated with them in natural distribution. Other kinds of plants and plant associations require on the contrary a neutral or alkaline soil.

It is the purpose of the present address to show how the leaves of trees in the process of the formation of leafmold produce at one time or under one set of circumstances a condition of soil acidity, at another time or under other circumstances a condition of alkalinity, and since the acidity of the soil is a fundamental factor in plant ecology, to point out that a knowledge of certain phenomena in the decay of leaves is essential to a correct understanding of the distribution of vegetation over the surface of the earth and its adaptation to the uses of man.

In the early experiments with blueberries it had been found that these plants grew successfully in certain acid soils composed chiefly of partially rotted oak leaves. On the rather natural assumption that the more thoro the decomposition of this material the more luxuriant would be the growth of the blueberry plants, some old oak leafmold was secured for further experiments. It had been rotting for about five years and all evidences of leaf structure had disappeared. It had become a black mellow vegetal mold.

When blueberry plants were placed in mixtures containing this mold they did not respond with luxuriant growth. On the

[1] Address of the retiring President, Washington Academy of Sciences, presented at the annual meeting of the Academy, January 16, 1913.

contrary their leaves turned purple and afterward yellowish, their growth dwindled to almost nothing, and at the end of the season when compared with other blueberry plants grown in a soil mixture in which the oak leafmold was replaced by only partially decomposed oak leaves the plants in the oak leafmold were found to weigh only one-fifth as much as the others. This astonishing result is exactly contrary to the ordinary conception. We have been accustomed to believe that the more thoroly decomposed the organic matter of a soil the more luxuriant its vegetation. In this case, however, thoro decomposition of the soil was exceedingly injurious to the plants.

This remarkable difference in effect between partially decomposed and thoroly decomposed oak leaves was found to be correlated with a difference in the chemical reaction of the two materials, the partially decomposed oak leaves being acid, when tested with phenolphthalein, and the oak leafmold alkaline.

With rose cuttings and alfalfa seedlings in the same two soils exactly opposite results followed, those in the oak leafmold making a luxuriant growth, those in the partially decomposed oak leaves showing every sign of starvation.

Every botanist is familiar with the rich woods where trillium, spring beauty, mertensia, and bloodroot delight to grow, in a black mellow mold made up chiefly of rotted leaves. He is familiar too with the sandy pine and oak woods where grow huckleberries, laurel, princess pine, the pink lady's slipper, and trailing arbutus. The soil here also is made up chiefly of rotting leaves and roots. Yet one does not look for trilliums in laurel thickets, or for arbutus among the bloodroots. Either habitat is utterly repugnant to the plants of the other.

Tests of the two habitats show that the trillium soil is alkaline, the other acid, reactions corresponding exactly to those observed in the cultural experiments already described, rose cuttings and alfalfa requiring an alkaline soil, blueberries an acid soil. The difference is as conspicuous in nature as in the laboratory and the greenhouse. What are the conditions under which rotting leaves develop these opposite chemical reactions?

In a ravine in the Arlington National Cemetery, near Washing-

ton, where the autumn leaf fall from an oak grove has been dumped year after year for many years, every stage in the decomposition of oak leaves may be observed, from the first softening of the dry brown leaf by rain to the black mellow leafmold in which all traces of leaf structure have disappeared. When freshly fallen the leaves show 0.4 normal acidity.[2] Those not familiar with the chemical expression "normal acidity" may perhaps most readily understand the term by reference to ordinary lemon juice, which has very nearly normal acidity in the chemical sense. Fresh oak leaves may be conceived therefore as having about one-third the acidity of lemon juice, gram to cubic centimeter. From a soil standpoint such a degree of acidity is exceedingly high. Probably no tree or flowering plant could live if its roots were imbedded in a soil as acid as this. A correct appreciation of the excessive acidity of freshly fallen leaves enables one to understand why it is that the leaves of our lawn trees, if allowed to lie and leach upon the grass, either injure or destroy it. On such neglected lawns the turf grows thin, mossy, and starved.

From the height of their initial acidity it is a long descending course thru the various stages of leaf decomposition to the point of chemical neutrality, and then upward a lesser distance on the hill of alkalinity, in the black leafmold stage.

In order to ascertain the rate of decomposition in leaves of various kinds, observations were begun in the autumn of 1909 on leaves of silver maple, sugar maple, red oak, and Virginia pine, exposed to the weather in barrels and in concrete pits. In one experiment a mass of trodden silver maple leaves 2 feet in depth, with an initial acidity of 0.92 normal, was reduced in a single year to a 3-inch layer of black mold containing only a few fragments of leaf skeletons and giving an alkaline reaction. In these experiments sugar maple leaves have shown a slower rate of decomposition than those of silver maple, while red oak leaves still show an acidity of 0.010 normal after three years of exposure,

[2] For a description of the method followed in determining the acidity see Coville, 1910, p. 27. Experiments in blueberry culture. Bulletin 193, Bureau of Plant Industry, U. S. Dept. Agri.

and leaves of Virginia pine an acidity of 0.055 normal under the same conditions.

The alkalinity of leafmold is due chiefly to the lime it contains, the lime content expressed in terms of calcium oxid often reaching 2 to 3 per cent of the dry weight. One sample had a lime content of 3.55 per cent. Many of the soils that result directly and exclusively from the decomposition of limestone have a lower percentage of lime than this. An alkaline leafmold containing 2 to 3 per cent of lime is properly regarded as a highly calcareous soil. Yet such a deposit may be formed in a region where the underlying soil is distinctly noncalcareous, the lime content of the soil being only a small fraction of 1 per cent and the soil reaction being acid. Whence comes the abundance of lime in an alkaline, richly calcareous leafmold formed over a soil distinguished by an actual poverty of calcareous matter?

If the leafmold is rich in lime the leaves from which it is derived should also be rich in lime. A determination of the amount of calcium oxid in the dried freshly fallen leaves of some of our well known trees shows this to be true, as illustrated by the following selections:

Kind of leaves	*Per cent of calcium oxid*
Red oak (*Quercus rubra*)	1.73
Silver maple (*Acer saccharinum*)	1.88
Pin oak (*Quercus palustris*)	1.91
Sweet gum (*Liquidambar styraciflua*)	1.92
Bur oak (*Quercus macrocarpa*)	2.39
Sugar maple (*Acer saccharum*)	2.56
Tulip tree (*Liriodendron tulipifera*)	2.84
Hickory (*Hicoria myristicaeformis*)	3.66
Gingko (*Ginkgo biloba*)	4.38

It should be understood that the lime thus shown does not exist in the leaf in the form of actual calcium oxid. It is largely combined with the acids of the leaf and serves in part to neutralize them, but is insufficient in amount to effect a complete neutralization. In all the kinds of leaves and herbage thus far examined, the net result is an acid condition altho lime may be present in large amount. Thus in the leaves of silver maple a condition of excessive acidity exists, about 0.9 normal, notwithstanding the presence of nearly 2 per cent of lime.

As the decomposition of such leaves progresses the acid substances are disorganized and largely dissipated in the form of gases and liquids, while the lime being only slightly soluble remains with the residue of decomposition, the black leafmold, and renders it alkaline.

In soils poor in lime, trees and other plants constituting the vegetative mantle of the earth may be regarded as machines for concentrating lime at the surface of the ground. This lime is drawn up by the roots in dilute solution from lower depths, is concentrated in the foliage, and the concentrate is transferred to the ground by the fall and decomposition of the leaves. The proverbial agricultural fertility of the virgin timberlands of our country was undoubtedly due in large part to the lime accumulated on the forest floor by the trees in preceding centuries, and to the consequent alkalinity of such surface soils when the timber had been removed and the leaf litter was thoroly decomposed. After a generation or two of reckless removal of crops the surface accumulation of lime was depleted and unless the underlying soil was naturally calcareous a condition of infertility ensued which for the purposes of ordinary agriculture could be remedied only by the artificial application of lime.

The chief agents in the decay of leaves are undoubtedly fungi and bacteria. There are other agencies, however, that contribute greatly to the rapidity of decay. Important among these are earthworms, larvae of flies and beetles, and myriapods or thousand-legged worms. Animals of all these groups exist in myriads in the leaf litter. They eat the leaves, grind them, partially decompose them in the process of digestion, and restore them again to the soil, well prepared for the further decomposing action of the microscopic organisms of decay.

The importance of earthworms in hastening the decay of vegetal matter was pointed out long ago by Darwin in his classical studies on that subject. The importance of myriapods, however, as contributing to the formation of leafmold has not been adequately recognized. In the canyon of the Potomac River, above Washington, on the steeper forested talus slopes, especially those facing northward, the formation of alkaline leafmold is in active

progress. The purer deposits are found in pockets among the rocks, where the leafmold is not in contact with the mineral soil and does not become mixed with it. The slope directly opposite Plummer's Island is a good example of such localities. Here during all the warm months the fallen leaves of the mixed hardwood forest are occupied by an army of myriapods, the largest and most abundant being a species known as *Spirobolus marginatus*. The adults are about 3 inches in length and a quarter of an inch in diameter. They remain underneath the leaves in the day time and emerge in great numbers at night. On one occasion a thousand were picked up, by Mr. H. S. Barber, on an area 10 by 100 feet, without disturbing the leaves. On another occasion an area 4 by 20 feet yielded 320 of these myriapods, the leaf litter in this case being carefully searched. Everywhere are evidences of the activity of these animals in the deposits of ground up leaves and rotten wood. Careful measurements of the work of the animals in captivity show that the excrement of the adults amounts to about half a cubic centimeter each per day. It is estimated on the basis of the moist weight of the material that these animals are contributing each year to the formation of leafmold at the rate of more than two tons per acre.

The decay of leaves is greatly accelerated also when the underlying soil is calcareous and alkaline, it being immaterial whether the lime is derived from a limestone formation or is a concentrate of the vegetation. On the rich bottomland islands of the upper Potomac the autumn leaf fall barely lasts thru the following summer, so rapid is its decay. These bottomlands have an alkaline flora, and they are found to have an alkaline reaction, caused by the lime brought to them in the flood waters.

The acceleration of leaf decay by an alkaline substratum is due to the prompt neutralization of the acid leachings of the leaves and also to the fact that such a substratum harbors with great efficiency many of the most active organisms of decay, from bacteria to earthworms.

It must not be understood that in a state of nature the decomposition of leaves is always so simple and uniform a process as has been described, or that it always results in the formation of

an alkaline leafmold. The chief factors that contribute to the acceleration of leaf decay have already been enumerated, but there are other conditions of nature that obstruct and retard this process. Under certain conditions the progress of decomposition may be permanently suspended long before the alkaline stage is reached. The soils thus formed, altho high in humus like a true leafmold, have an acid reaction and a wholly different flora.

Examples of such suspensions of leaf decay are found in bogs, where the deposited vegetation is protected from the organisms of decay by submergence in non-alkaline water, and on uplands where the soil is derived from sand, sandstone, granite, or schist, in which there is not enough lime or other basic material to neutralize the acidity of the decaying leaves.

There is of course a supply of lime in the leaves themselves, and as a new layer of leaves is added to the soil each year it might be expected that there would result an unlimited concentration of lime in the surface soil and that all surface soils that supported a growth of vegetation would ultimately become alkaline. Such an indefinite accumulation of lime is prevented, however, by another factor which requires consideration. As soon as each successive layer of leaf litter is sufficiently decayed to permit the roots of plants to enter it and feed upon it, the lime it contains, together with other mineral constituents, begins to be absorbed. This loss of lime from the decaying leaves is sufficient, under many situations in nature, to prevent the decaying mass from reaching the alkaline stage. Decomposition is suspended while the leaf litter is still acid. True leafmold, with an alkaline reaction, is never formed under such conditions. The leaf deposit remains permanently acid and such areas bear an acid flora. In the vicinity of Washington one often sees hills of quartz gravel, wind-swept and rain-washed, where the soil contained little lime in the beginning, and none could be brought by flood waters or by the dust of the atmosphere. Characteristic plants of such hills are black jack oak, trailing arbutus, wild pansy, azalea, and huckleberry, all plants adapted to acute conditions of acidity. If one's front yard happens to coincide with

what was once such a spot, let him not undertake the herculean task of growing roses and a bluegrass turf. Let his lawn be of redtop and his shrubs be azaleas, laurel, and rhododendrons.

Another factor that contributes to the suspension of leaf decomposition is the acid leachings from each new deposit of autumn leaves. Various acidity determinations show that after lying exposed to the weather over winter, leaves ordinarily have only one-fifth to one-tenth the acidity they possessed when they fell to the ground. It has been found experimentally that the leachings from fresh leaves will serve to acidulate an underlying soil of moderate alkalinity. Unless therefore the conditions of a locality are such as to effect the decomposition of one year's leaf fall before the next year's deposit takes place, a permanent acid leaf cover is established. In many of the oak forests on the sandy coastal plain eastward from Washington there is a permanent accumulation of such material. The roots of the trees and undershrubs bind the half-rotted leaves into a dense mat. The principal trees are oaks. The principal shrubs that make up the dense underbrush belong to the Ericaceae and related families. There is no mellow leafmold nor any of the leafmold plants.

This kind of mat or turf is of such widespread occurrence, is so distinct in its appearance, and so characteristic in the type of vegetation it supports that it should have a name of its own, in order that it may come to be recognized as one of the important phenomena of nature.

Because if its resemblance to bog peat in appearance, structure, and chemical composition, and because it supports a type of vegetation similar to that of bog peat, it has been proposed to adopt for it the name upland peat. As defined in an earlier publication[3] upland peat is "a nonpaludose deposit of organic matter, chiefly leaves, in a condition of suspended and imperfect decomposition and still showing its original leaf structure, the suspension of decomposition being due to the development and maintenance of an acid condition which is inimical to the growth of the micro-organisms of decay."

[3] Coville, 1910, p. 34. Experiments in blueberry culture. Bulletin 193, Bureau of Plant Industry, U. S. Dept. Agri.

Upland peat would have become leafmold had not the orderly normal course of leaf decomposition been suspended and conditions of acidity established which rendered the further progress of that decomposition impossible.

The rate at which leaves decay is greatly influenced by temperature. In the cooler northern latitudes and at high elevations in lower latitudes the rate of decay is slower and the formation of upland peat is more general than in warmer climates. Except on calcareous soils the higher Apalachian peaks, from 4000 to 6000 feet, bear an almost continuous layer of upland peat, from a few inches to a foot or more in depth. Their great rhododendron thickets are rooted in deep beds of upland peat. The spruce forests of the higher New England mountains lay down a similar formation.

In the treeless west the decay of leaves where it is not actually suspended by dryness is rapid and complete. At the higher elevations, however, where the land begins to be timbered the organic matter does not fully decay, and in the heavily timbered areas the deposit of upland peat often becomes characteristically deep and continuous. In fighting creeping fires in the yellow pine forests at the lower elevations the favorite and most effective tool is the rake, which parts the light leaf litter and puts a stop to the progress of the flames. But in the dense fir and spruce timber the forest ranger's chief tools are the spade and the mattock, with which he must cut through the thick layer of dry peat to the mineral soil beneath if he is to effectually combat a slowly creeping fire.

So strong is the tendency to the formation of peat under the low temperatures and heavy precipitation of the high mountains that even on limestone soils a superficial layer of upland peat is sometimes accumulated. Such a condition exists on innumerable areas at an elevation of about 10,000 feet in the Manti National Forest of Utah. On the basaltic plateau of extreme northeastern Oregon, where the soil is naturally alkaline in reaction the lodgepole pine and Douglas fir forests at elevations of 5000 feet and over lay down a continuous bed of peat which supports a characteristic acid flora. A quantitative test of one of

the acid flora soils of this region, at an elevation of 8000 feet, showed the customary high acidity at the surface, and successively lower degrees of acidity underneath, until at the depth of 5 feet, at the surface of the basaltic rock, the reaction was neutral.

The group of plants that forms the best index to the acid character of a soil is the family Ericaceae, and the related families Vacciniaceae and Pyrolaceae. When these occur in vigorous growth on a calcareous soil or among calcareous rocks, as is sometimes reported, one may expect to find, as the speaker in his own experience has always found, that a layer of upland peat has been formed above the calcareous substratum and that in this superficial layer the roots of the plants find their nourishment, really in an acid medium, notwithstanding the alkalinity beneath.

Continued observations on the association of certain types of wild plants with acid and non-acid soils, supported by cultural experiments, are in all respects confirmatory of the theory that soil acidity is one of the most influential factors in plant distribution and plant ecology.

The relation of leafmold to the existence of acid or non-acid soil conditions may now be viewed with appreciative recognition. If the conditions in any area are such that the decay of leaves follows the uninterrupted course that leads to the formation of leafmold a state of soil alkalinity is reached, with all the resultant effects on the growth and distribution of the native vegetation. If on the other hand the conditions are such that the course of decay is diverted into the channel that ends in the formation of peat, a condition of permanent acidity is indicated, with the accompaniment of all those peculiar plant phenomena which are characteristic of such a state.

It is perhaps desirable to call attention here to the fact that while partially decomposed vegetation appears to be the chief source of soil acidity there are mineral constituents of the soil, of wide distribution and great abundance, which are also acid in reaction. The acidity of which we hear so much in agricultural writings as characteristic of soils worn out by long years of careless farming is doubtless due in large part to a natural mineral acidity unsheathed by the removal of the lime that once neutralized

it for like the leaves of trees many of the crops of agriculture are heavy with lime and their uncompensated removal year after year has its inevitable cumulative result.

The speaker hopes that he does not overstep the proper bounds of this address if he calls attention to conditions in bog deposits which almost exactly parallel the two types of terrestrial organic formation, leafmold and upland peat. In bogs with alkaline waters, as for example those underlain by marl, a condition of permanent acidity is not maintained in the lower strata of the deposit. As far upward as the alkaline waters penetrate, the antiseptic acids are not present, decay continues, and the resulting formation is not peat, but a plastic fine-grained black material that may best, perhaps, be designated by that much misused term muck. Muck corresponds in bog deposits to leafmold in upland deposits, contrasting with bog peat as leafmold contrasts with upland peat.

We may follow this idea one step further. Coal is petrified peat. As the purest peats are not formed in alkaline waters, it can not be expected that the best coal will be found in situations indicative of alkaline conditions. If coal is found immediately overlying beds of marl or limestone it is to be expected that such coal will be of an impure type corresponding in origin to muck. The speaker takes the liberty of suggesting to his geological friends that in reconstructing in theory the climatic and other conditions under which the various kinds of coal were deposited they may safely hypothesize that the purer coals were laid down in waters that were acid.

Allusion has been made to the peculiar characteristics of plants that inhabit peat. Among these peculiarities perhaps none is more remarkable than the presence of mycorhizal fungi on the roots of many, perhaps most, peat-loving plants. It is known that peat is very poorly supplied with nitrogen in the form of nitrates, which most plants of alkaline soils appear to require. Organic nitrogen, however, is abundant in peat and there is very strong evidence that these mycorhizal fungi take up this organic nitrogen, and possibly atmospheric nitrogen also, and transfer it in some acceptable form to the plants in whose roots

they live. Unfortunately the work of botanists on these fungi has been confined largely to the determination of the mere anatomical fact of their occurrence on the roots or in certain of the root cells, with descriptions of their size and configuration. Little attention has been paid to the isolation of the fungi, their culture and identification, or to the demonstration of their physiological action. The only hypothesis, however, that satisfactorily explains what we already know about the mycorhizal fungi is that they prevent the nitrogen starvation of peat-inhabiting plants. It is well known that certain peat-bog plants, as for example sundew, trap insects, digest them, and assimilate their nitrogen. It is to be hoped that within a few years we shall be equally well informed about the function of the mycorhizal fungi. But even now we may speak of their probable function with confidence.

The mycorhizal fungi are known to occur on most of the trees that inhabit acid situations, for example chestnut, beech, oaks, and conifers. The ordinary hillside pasture in New England is a mycorhizal cosmos. The clubmosses have them, the sweet fern, the blueberries, the ferns, the orchids. In our sandy pine and oak woods about Washington almost all the vegetation possesses mycorhizal fungi. One comes to think of the giant oaks as dependent on these minute organisms.

Were Solomon to write a new edition of the Proverbs today I am sure that he would tell us "There be four things which are little upon the earth, but they are exceeding strong," and that among the four he would include "The little brothers of the forest, they seek not the light but the leafy earth; they prepare for the oak the strength that is his."

Our American agriculture, derived in the main from the agriculture of the Mediterranean region, and that in turn from the older agriculture of Persia, is chiefly made up of plants that thrive best in alkaline or neutral soils. Altho many of our soils in the eastern United States are naturally acid we try with only indifferent success to grow in them these alkaline plants of southern Europe and the East. Altho some of our agricultural plants are tolerant of acidity, our agriculturists have not yet recognized the possibility of building up for acid soils a special agriculture

in which all the crops are acid-tolerant. We may yet, perhaps, utilize for agricultural purposes even the sandy acid lands of the coastal plain instead of turning them over as we now do to the lank huckleberry picker, whose lonesome garden is all that he is able to reclaim by present methods from the imaginary wilderness that surrounds him. Yet these lands contain all sorts of delicious native fruits, and a natural vegetation rich and luxuriant after its own manner.

Had our agriculture originated not in the alkaline soils of the Orient but among the aboriginal peoples of the bogs of Scotland or of the sandy pine barrens of our Atlantic Coastal Plain we should have entirely different ideas of soil fertility from those we now possess. If our cultivated fruits were large and otherwise improved forms of the blueberry, the service berry, the thornapple, and the beach plum, if our only grains were rye and buckwheat and our only hay redtop and vetch, and if our root crops consisted of potatoes, carrots, and onions, our high-priced agricultural lands would be the light sandy acid soils and the drained bogs, while our deep limestone soils would be condemned to use for the pasturage of cattle and of sheep.

Thus far man has devoted himself largely to the utilization of the plants of the leafmold, which have gathered up for him the wealth of the earth. Let him now, I say, turn his attention also to the plants of the peat and try whether they will not yield to him in increased measure the luxuriance of foliage and of fruit that they have always yielded without assistance to nature herself.

ABSTRACTS

Authors of scientific papers are requested to see that abstracts, preferably prepared and signed by themselves, are forwarded promptly to the editors. Each of the scientific bureaus in Washington has a representative authorized to forward such material to this journal and abstracts of official publications should be transmitted through the representative of the bureau in which they originate. The abstracts should conform in length and general style to those appearing in this issue.

PHYSICAL CHEMISTRY.—*The binary system*: $Na_2Al_2Si_2O_8$ (*nephelite, carnegieite*)—$CaAl_2Si_2O_8$ (*anorthite*). N. L. BOWEN. American Journal of Science, **33**: 551–573. 1912.

The study of the system $Na_2Al_2Si_2O_8$ – $CaAl_2Si_2O_8$ was undertaken because of the importance of these compounds as rock-forming constituents. It was found that the soda compound exhibits enantiotropism with the inversion point at 1248°. The low temperature form (nephelite) crystallizes in the hexagonal system with a habit similar to that of natural nephelite. The high-temperature form is triclinic. It has no natural analogue and has been given the name carnegieite. Carnegieite melts at 1526°.

The lime compound occurs only in the triclinic form, anorthite, and melts at 1550°.

Both carnegieite and nephelite are capable of holding the lime compound in solid solution, the former 5 per cent and the latter as much as 35 per cent.

The effect of solid solution on the inversion-point was well shown by the system. The temperature of inversion rises considerably as the amount of the lime compound in solid solution increases.

The optical constants of the components were carefully determined. Crystals of the artificial nephelite were measured on the goniometer and their hexagonal nature confirmed. It was especially gratifying to be able to determine definitely the variation, with composition, of the optical properties of the hexagonal mix-crystals (nephelite). With increasing proportion of the lime molecule the birefringence of 0.004 (negative) becomes less, passes through zero, and finally becomes 0.002 (positive).

The problem as a whole, although in some measure complicated, was found capable of very definite laboratory solution. The extension of the study to include the potassium-bearing nephelites has already been begun. N. L. B.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

THE ANTHROPOLOGICAL SOCIETY OF WASHINGTON

A special meeting of the Anthropological Society of Washington was held January 7, 1913, in the National Museum, with the President, Mr. GEORGE R. STETSON in the chair.

Mr. E. DANA DURAND, Director of the Census read a paper on *Race statistics of the last census*. During the decade 1900–1910 the white population of the United States increased about 22 per cent and the negro about 11 per cent. This difference is partly due, however, to the direct or indirect effect of immigration of whites, in the absence of which the whites would have increased about 14 per cent. The Indians increased about 12 per cent, the Chinese decreased in number, while the Japanese nearly trebled. The whites have at practically every census shown a more rapid rate of increase than the negroes, and there is reason to believe that the difference between the two races in rate of increase from 1890 to 1900 was greater than appeared from the census returns, on account of a probable underenumeration of the negroes in 1890. The census of 1910 showed that about 21 per cent of the negroes are mulattoes, as compared with about 12 per cent in 1870, the last preceding census at which the question regarding blood mixture was asked in comparable form.

There has been no very great migration of negroes out of the South, nearly nine-tenths of the total number being still found in that section. The number living outside the South increased 167,000 between 1900 and 1910, while the number residing in the South increased over 800,000. The rate of natural increase—that is, by excess of births over deaths—of the white population of the South, however, is much higher than that of the negroes, being higher also than that of the whites in the North.

Among the native white population whose parents were born in this country, there were, in 1910, 104 males to each 100 females, as compared with only 98.9 in the case of the negroes. Among all classes of the population more boy babies than girl babies are born, but equality tends to be brought about by a higher death rate among the males. The difference in sex distribution between the whites and the negroes is probably attributable, in part at least, to more favorable health conditions among the whites.

The age distribution of the native white population is somewhat different from that of the negroes, probably chiefly on account of a lower death rate among whites, tending to greater longevity. There has apparently been a very marked decline in the birth rate among negroes in recent years, while there had been a gradual but less marked decline in the birth rate of the whites during each decade for a long period of time.

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Negroes tend to marry earlier than the native white classes; and, in fact, at all age periods the proportion of married, widowed, and divorced persons, taken together, is higher in the case of the negroes of both sexes than in the case of the native whites of native parentage.

There has been a marked change in the composition of the foreign-born population of the United States during recent years. Natives of northwestern Europe constituted more than two-thirds of the total foreign-born population of the United States in 1900, but less than half in 1910, while southern and eastern Europeans formed only a little over one-sixth of the total at the earlier census, as compared with three-eights in 1910. The Germans and the Irish particularly have fallen off conspicuously in numbers, while the natives of Russia—largely Russian Jews and Poles—Austria, Hungary, Italy, Greece, and other countries of southern and eastern Europe have increased by very high percentages, no lesss than 1090 per cent in the case of natives of Greece. The natives of Russia now rank second among the foreign-born classes, and those of Italy fourth.

Various inquiries, accompanied by additional statements of facts and explanations, were answered by Mr. Durand, but there was no discussion beyond these. WM. H. BABCOCK, *Secretary.*

THE BOTANICAL SOCIETY OF WASHINGTON

The 12th annual business meeting was held on Wednesday, October 30, 1912. Officers were elected as follows: President, W. W. STOCKBERGER; Vice-President, C. R. BALL; Recording Secretary, H. L. SHANTZ; Corresponding Secretary, C. L. SHEAR; Treasurer, F. L. LEWTON.

The executive committee reported an active membership of 108.

The 83rd regular meeting was held at the Cosmos Club November 12, 1912. The following papers were read:

A portrait of Linnaeus: Dr. J. N. ROSE. Doctor Rose exhibited an engraved portrait of Linnaeus which had recently been presented to the Smithsonian Institution by Captain John Donnel Smith, of Baltimore who had previously given to that Institution his magnificent herbarium and library. This portrait is one rarely seen in this country, being a mezzotint of one of the earliest portraits of Linnaeus, the original being a replica of Hoffman's famous picture showing Linnaeus in Lapland dress, of which the original is now the property of the Clifford family. This replica was known to have been in the possession of one Thornton as late as 1811; but its whereabouts now is not known.

Doctor Rose also called attention to the large collection of portraits of Linnaeus in the possession of the Linnean Society, and also to the work of Tycho Tullberg, "Linne-porträtt," a quarto volume of 185 pages with 25 portrait plates.

Rough-bark disease of the yellow newtown pippin: Mr. JOHN W. ROBERTS.

Botanizing in the region of the natural bridges of southern Utah: Dr. P. A. RYDBERG (by invitation).

C. L. SHEAR, *Corresponding Secretary.*